Mesoscopic organization, quantum defects and glassiness in strongly correlated materials

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Competing interactions on different length scales are able to stabilize mesoscale phase separations and create spatial inhomogeneities in a wide variety of systems. Examples are stripe formation in doped Mott insulators, as found in transition metal oxides, domains in magnetic multilayer compounds or mesoscopic structures formed by assembling polymers in solution and amphiphiles in water-oil mixtures. In all these cases the tendency towards a perfectly ordered array of domains, stripes etc. is undermined by frustrating long range interactions. Very often, these assemblies exhibit a long time dynamics similar to the relaxation seen in glasses. Because of this qualitatively new behavior it has been speculated that there are new organizing principles on the meso and nano scale, driven by strong correlations on an atomic scale [1].

Recently, we developed a new theoretical framework for the investigation of non-equilibrium behavior and glassiness of quasi one-dimensional charge inhomogeneities, i.e stripes, in strongly interacting transition metal oxides [2]. We showed that an energy landscape with an exponentially large number of metastable configurations emerges in a system characterized by the competition between local phase separation and long range Coulomb interaction. This leads to a glass transition driven by an “entropy crisis” and anomalous long time dynamics. This stripe glass is *self generated*, implying that the barriers characterizing the activated dynamics are rather universal and should not depend on details like added impurities but only on the generic interactions on short and long scales, i.e. the magnetic exchange interactions and the Coulomb interaction. This universality agrees with magnetic resonance experiments. We find that the entropy crisis causes a break up of the stripe glass into a mosaic of domains or droplets, built up by the various metastable states, which determines the dynamics of motions.

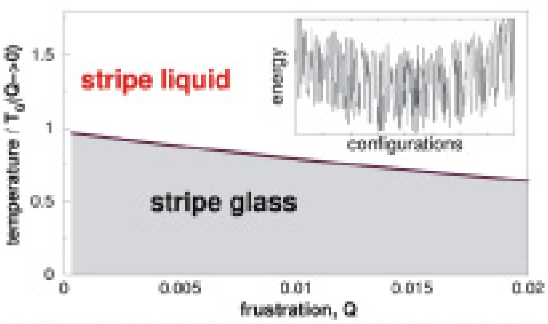

Figure 1: Phase diagram of a self generated stripe glass, where T_0 ($Q\to 0$) is the glass temperature for small frustration, Q. The inset shows a typical energy landscape of such a glass.

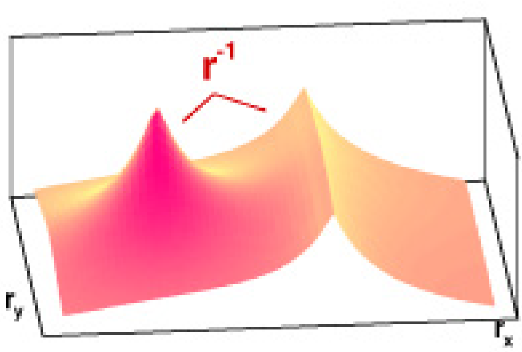

Figure 2: Spatial variation of the magnetization along a line and a point defect close to a magnetic quantum critical point.

In almost all cases correlated materials are located in the vicinity of numerous competing phase transitions. Examples are giant magneto-resistance manganites, magnetic semiconductors, cuprate and organic superconductors and heavy fermion systems. At low temperatures the quantum nature of these phase transitions becomes increasingly more important, making these materials very sensitive to imperfections or defects. In fact, one can even use defects to probe new properties of a material close to a quantum critical point [3].

The analysis of the inhomogeneous magnetization in the vicinity of planar, line or point defects revealed that at the critical point a long range interaction between defects results [4]. We found that, together with an anomalous dynamics due to the interaction between defects and metal electrons, drastic changes of the magnetic properties of the host material result. This holds the promise for the design of materials which, due to their new properties on mesoscopic length scales, are particularly sensitive to mechanical or chemical pressure and magnetic fields.

References: [1] R. B. Laughlin, D. Pines, J. Schmalian, B. Stojkovic, and P. G. Wolynes, *Proceedings of the Natl. Academy of Sciences* **97,** 32 (2000). [2] J. Schmalian, and P, G. Wolynes, *Phys. Rev. Lett.* **85**, No. 4 (2000). [3] D. K. Morr, J. Schmalian, R. Stern, C. P. Slichter, *Phys. Rev. Lett.* **80**, 3662 (1998); *Phys. Rev B* **58,** 11193 (1998). [4] A. J. Millis, D. K. Morr, and J. Schmalian *submitted to Phys. Rev. Lett.*